CHAPTER 10: NATIONAL IMPACT ANALYSIS

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CHAPTER 10: NATIONAL IMPACT ANALYSIS

10.1 INTRODUCTION

The Energy Policy and Conservation Act (EPCA) states that any new or amended standard must be chosen so as to achieve the maximum improvement in energy efficiency that is technologically feasible and economically justified. In determining whether economic justification exists, the Department must determine that the benefits of the candidate standard level exceed its burdens to the greatest extent practicable. Key factors in this decision are:

- the total projected amount of energy savings likely to result directly from the imposition of the standard, and

- the savings in operating costs throughout the estimated average life of the covered product in the type (or class) compared to any increase in the price of, or in the initial charges for or maintenance expenses of, the covered products which are likely to result from the imposition of the standard.

To satisfy this EPCA requirement and to more fully understand the national impact of potential efficiency regulations for distribution transformers, the Department conducted a national impact analysis. This analysis assessed future national energy savings (NES) from candidate transformer standards as well as the national economic impact using the net present value (NPV) metric.

The NES is the cumulative incremental energy savings from a transformer efficiency standard relative to a base case scenario of no national standard over a forecast period. The Department calculated NES for each candidate standard level in units of quadrillion Btus (Quads) for standards that it assumed will be implemented in the year 2007.

The NPV is the net present value of the incremental economic impact on consumers from a candidate standard level. The Department calculated the NPV using a method similar to the NES, except that it estimated incremental costs and benefits instead of energy, and discounted the net benefits rather than calculating them as an un-discounted sum. The Department discounted purchases and expenses and operating costs for transformers using a national average discount factor. The Department calculated the NPV impact from transformers that were purchased between 2007 through 2035 to calculate the total NPV impact from purchases during the forecast period.

The Department developed a Microsoft Excel® spreadsheet, the national impact spreadsheet, to implement the calculations described above. The spreadsheet calculates capacity and operating cost savings associated with each of the candidate standard levels. The NES analysis considers cumulative energy savings through the year 2035, while the NPV considers capacity and operating cost savings through the year 2070[a] for transformers purchased on or before 2035. By taking the difference between the base case scenario and candidate standard levels, summing and discounting the annual results, the spreadsheet calculates an NPV for each candidate standard level relative to the base case.

10.1.1 National Impact Spreadsheet Flowchart

Figure 10.1.1 presents a graphical flow diagram of the distribution transformer national impact (NES and NPV) model and spreadsheet. In the diagram, the arrows show the direction of information flow of the calculation. The information begins with inputs that are shown as parallelograms. As information flows from these inputs, it may be integrated into intermediate results (shown as rectangles) or through integrating sums or differences (shown as circles) into major outputs that are shown as boxes that have a curved bottom edge. Note that the shipments model portion of the flow diagram (shaded) is discussed in Chapter 9.

[a] The Department chose the year 2070 because it is the rounded sum of 2035 plus 32 years, the average lifetime of distribution transformers.

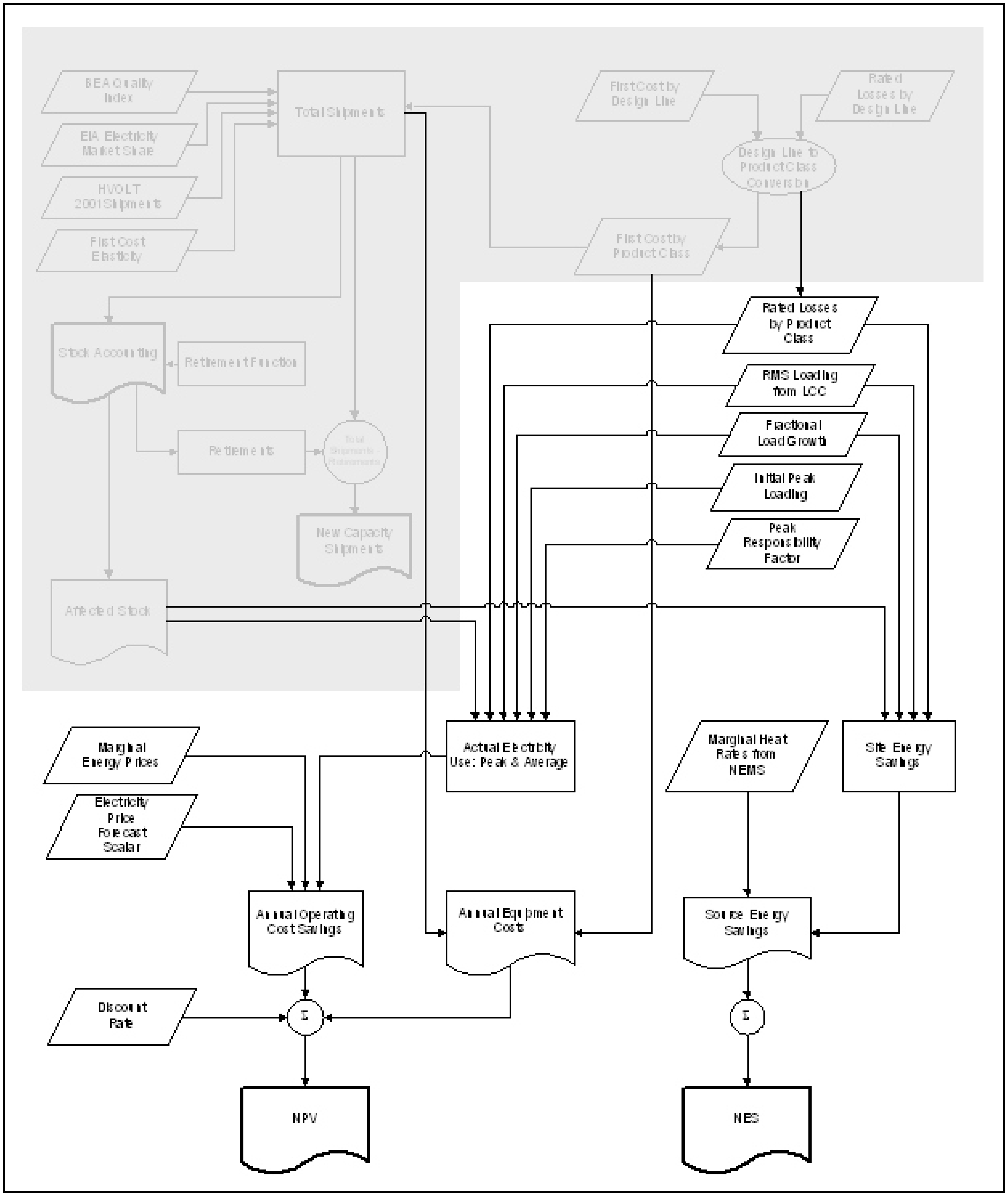

Figure 10.1.1 National Impact Analysis Flowchart

The calculation starts with the shipments model (described in Chapter 9) which integrates the inputs of 2001 shipments estimates from the Department's contractor,[1] the U.S. Bureau of Economic Analysis (BEA) transformer quantity index,[2] electricity market shares from the U.S. Energy Information Administration (EIA),[3] and equipment price estimates from the life-cycle cost analysis (LCC) to produce a backcast and a forecast of total shipments. The total shipments and a retirement function feed an accounting of in-service transformers (stocks) to produce estimates of the stock that is affected by candidate standards and transformer retirements. When subtracted from total shipments, the transformer retirements produce new capacity shipments, which are those transformers made to supply new electrical capacity.

After the shipments calculation, the NES and NPV calculations begin. Key inputs from the LCC analysis are the average rated losses for both no-load and load losses, and the cost of transformers including installation. The losses and the equipment costs then go through a transformer size and product class adjustment that converts the data from representative design lines to average product class information. Additional inputs regarding average and peak losses —including root mean square (RMS) loading, peak loading, and peak responsibility factor—allow a conversion from rated losses into actual losses. At this point, the information flow for the NES and NPV calculation splits into two paths.

On one path, the NES calculation sums the watt-hours of energy consumed by the affected stock, and takes the difference between the base case and standards scenario to calculate site energy savings. Marginal heat rates from the National Energy Modeling System (NEMS) then convert the site energy savings to energy savings at the source (i.e., at the power plant). The marginal heat rates from NEMS includes the transmission and distribution losses. The Department performed a sensitivity analysis to analyze an improvement in the heat rate as a result of the efficiency improvement in the standards scenario and the impact was not significant. The sum of annual energy savings for the forecast period through 2035 then provides the final NES number.

On the other path, the NPV calculation brings in marginal price inputs from the LCC analysis for both energy costs and capacity costs and for both load losses and no-load losses. The marginal prices, when combined with the actual peak and average losses, provide the estimate of the operating cost. Meanwhile, the adjusted equipment installed cost times the annual shipments provides the estimate of the total annual equipment costs. The Department took three differences to calculate the net impact of the candidate standard. The first difference was between the candidate standards scenario equipment costs and the base case equipment costs to obtain the net equipment cost increase from a candidate standard. The second difference was between the base case scenario operating cost and the candidate standards scenario operating cost to obtain the net operating cost savings from a candidate standard. The third difference was between the net operating cost savings and the net equipment cost increase to get the net expense/savings for each year. The Department then discounted the net expense/savings to 2001 and summed them over the years 2007-2070 for transformers purchased on or before 2035, to provide the NPV impact of a candidate standard.

Given this overview, the Department provides detailed technical descriptions of the three models below: the shipments model in Chapter 9, the NES model in section 10.2, and the NPV model in section 10.3. Each technical description begins with a summary of the model. It then provides a descriptive overview of how the Department performs each model's calculations, and follows with a summary of the inputs. The final subsections of each technical description describe each of the major input and computation steps in detail and with equations, when appropriate. After the technical model descriptions, the Department presents the results of the national impact calculations.

10.2 NATIONAL ENERGY SAVINGS

The Department developed the NES model to estimate the total national energy savings using the results from the shipments model, combined with information from the LCC on energy savings. The savings shown in the NES reflect decreased losses from the installation of new, more-efficient transformer units nationwide in comparison to a base case with no national standards. The NES predicts the energy savings for each of several candidate standard levels. Positive values of NES correspond to net energy savings, i.e., a decrease in energy consumption with standards in comparison to the energy consumption in the base case scenario.

10.2.1 National Energy Savings Overview

The Department calculated the cumulative incremental energy savings from a candidate transformer efficiency standard relative to a base case scenario of no standard over the forecast period. The Department calculated NES for each candidate standard level in units of quads for standards that it assumed will be implemented in the year 2007. The NES calculation started with transformer shipments and stocks (in-service transformers), estimates of which are outputs of the shipments model (Chapter 9). The Department then obtained estimates of transformer losses from the LCC analysis (Chapter 8). The Department proceeded to calculate the total energy use by the stock of transformers for each year for both a base case and standards case. Over time, in the standards case, more-efficient transformers gradually replace less-efficient transformers. Thus, the energy per unit capacity used by the stock of transformers gradually decreases in the standards case relative to the base case. The Department converted energy used by the transformers into the amount of energy consumed at the source of electricity generation (the source energy) with a site-to-source conversion factor. The site-to-source factor accounts for transmission, distribution, and generation losses. For each year analyzed, the difference in source energy use between the base case and standards scenario is the annual energy savings. The Department summed the annual energy savings from 2007 through 2035 to calculate the total NES for the forecast period.

In calculating the NES, the Department did not assume any trends in transformer name-plate efficiency besides the incremental efficiency improvement indicated by the LCC calculation. The Department also assumed that the efficiency of transformers did not degrade over time. This means that the annual energy savings can be written in terms of an affected stock described in section 9.3.10 in the shipments chapter:

$$AES(y) = (UEC_{Base} - UEC_{Std}) \times Aff\_Stock(y) \qquad \textbf{Eq. 10.1}$$

where:

$AES(y)$	=	the annual energy savings in year y,
$Aff\_Stock(y)$	=	stock of transformers of all vintages that are operational in year y,
UEC_{Base}	=	the site unit energy consumption for the base case, and
UEC_{Std}	=	the site unit energy consumption for the standards case.

Then, given the annual energy savings, the NES can be calculated as a simple sum:

$$NES = \sum_{y=Std\_year}^{2035} SiteToSource(y) \times AEC(y) \qquad \textbf{Eq. 10.2}$$

where:

$SiteToSource(y)$	=	the site-to-source conversion factor in year y, and
AEC	=	the annual energy consumption.

Once the shipments model provides the estimate for the affected stock, the key to the NES calculation is in calculating UEC_{Base} and UEC_{Std}, given the input from the LCC and including the site-to-source conversion factor that translates site energy into energy consumed at the power plant. In the next section, the inputs necessary for the NES calculation are summarized, and then presented individually with complete technical detail.

10.2.2 National Energy Savings Inputs

The NES model inputs fall into three broad categories: (1) some inputs help convert the data from the LCC into data for the product classes and transformer size distributions used in the NES; (2) some inputs help calculate the unit energy consumption; and (3) the site-to-source factors then enable the calculation of source energy consumption from site energy use. The specific list of NES model inputs is as follows:

1. Size Scaling of Losses and Costs

2. Mapping of LCC Design Line Data to Product Classes

3. Root Mean Square Loading

4. Load Growth

5. Effective Date of Standard

6. Unit Energy Consumption

7. Electricity Site-to-Source Conversion

8. Affected Stock

The size scaling of losses and costs adjusts LCC representative design line data so it can represent the size distribution of transformers that are in a particular product class. The mapping of LCC design line data to product classes provides the proper inter-design line averaging or adjustments for representation of the product classes (i.e., the design-line to product-class relationship is a many-to-many relationship so the mapping needs to be carefully specified). The RMS loading is a key factor in estimating actual load losses given the load losses at rated load for a transformer. Load growth over the lifetime of the transformer can modify the average (RMS) loading that is seen by an affected stock of transformers. The effective date of the standard impacts the definition of the affected stock. The unit energy consumption is the energy per unit capacity of an affected stock of transformers and depends on all of the first four inputs. Finally, the electricity site-to-source conversion provides the estimate of energy consumption at the power plant given the site energy use of the transformer.

The next section begins the detailed discussion of NES inputs with a description of the size-scaling method that adjusts transformer losses and costs from a representative LCC design line to the distribution of sizes in a transformer product class.

10.2.2.1 Size Scaling of Losses and Costs

The size scaling of losses and costs is the scaling relationship or equation that the Department used to project the economic results from one transformer design line to similar transformers of different sizes. It is a key element in adjusting losses and costs from a representative transformer in the LCC to a distribution of transformer sizes represented in the NES calculation.

As described in the engineering analysis, the Department applied the 0.75 power scaling rule (the “0.75 rule”) for projecting losses and costs from one design line to transformers of other sizes. In the NES calculation, shipments are calculated in terms of installed capacity. The losses associated with a stock of transformers, and the costs associated with a capacity shipped, are estimated by multiplying the relevant capacity times the average losses, or costs per unit capacity. Before applying the 0.75 rule, the Department calculated the losses and costs per unit of installed capacity within a given engineering design line. Then the Department calculated an adjustment factor using the 0.75 rule to account for the fact that the representative design line unit used in the engineering analysis is not exactly the “average” transformer size for the set of transformers that design line represents. This adjustment factor is given by the following equation:

$$AdjFactor = \sum_i \left[Ship_i \times Cap_i^{0.75}\right] / \left(Cap_{DL} \times \sum_i Ship_i\right) \qquad \textbf{Eq. 10.3}$$

where:

AdjFactor	=	adjustment factor that gives the shipments-weighted losses or costs per transformer when multiplied by the design line losses or costs,
$Ship_i$	=	shipments in the i-th size category,
Cap_i	=	the rated capacity for the transformers in the i-th size category, and
Cap_{DL}	=	the rated capacity of the design line.

The Department also used the shipment-weighted average size of transformers represented by a particular design line to calculate the average loss per capacity ($AvgLossPerCap_{DL}$), as described in the following equation:

$$AvgLossPerCap_{DL} = LossPerCap_{DL} \times AdjFactor \times Cap_{DL} / Cap_{avg} \qquad \textbf{Eq. 10.4}$$

where:

$LossPerCap_{DL}$	=	the loss, or cost per unit capacity, for the design line unit from the LCC analysis, and
Cap_{avg}	=	the shipment-weighted average size of transformers represented by a particular design line.

Once the losses and costs from the LCC represent the correct size distribution, they need a further adjustment so that they represent the appropriate product classes, as described in the next section.

10.2.2.2 Mapping LCC Design Line Data to Product Classes

The NES and NPV calculations use the LCC calculations as the source of most input data. The LCC calculations are performed by design line, whereas any eventual standards would be promulgated by product class. As a first step, therefore, the NES calculation aggregates the LCC design line data to product classes. Design-line-to-product-class aggregation is the process by which the Department took the results from an economic analysis of engineering design lines and combined them to provide estimates of economic impact by product class.

To represent the variety of designs in some product classes, the Department analyzed up to three different design lines per product class. Specifically, product class 1 (single-phase, medium-voltage, liquid-immersed transformers) is represented by three design lines and product class 2 (three-phase, medium-voltage, liquid-immersed transformers) is represented by two design lines. The Department did not specifically examine single-phase, dry-type design lines. For single-phase product classes 5, 7, and 9, the Department used the appropriate three-phase design lines divided by 3. Table 10.2.1 presents the mapping of design line to product class.

Table 10.2.1 Mapping of Design Line (DL) to Product Class (PC)

Product Class	BIL* (kV)	Capacity (kVA)	Mapping
PC 1, Liquid-Immersed, MV,** Single-Phase	Any	10-833	DL 1 + DL 2 + DL 3
PC 2, Liquid-Immersed, MV, Three-Phase	Any	15-2500	DL 4 + DL 5
PC 3, Dry-Type, LV,† Single-Phase	≤ 10	15-333	DL 6
PC 4, Dry-Type, LV, Three-Phase	≤ 10	15-1000	DL 7 + D L8
PC 5, Dry-Type, MV, Single-Phase	20-4	15-833	(DL 9 ÷ 3) +(DL 10 ÷ 3)
PC 6, Dry-Type, MV, Three-Phase	20-45	15-2500	DL 9 + DL 10
PC 7, Dry-Type, MV, Single-Phase	46-95	15-833	(DL 11 ÷ 3) +(DL 12 ÷ 3)
PC 8, Dry-Type, MV, Three-Phase	46-95	15-2500	DL 11 + DL 12
PC 9, Dry-Type, MV, Single-Phase	≥ 95	75-833	DL 13 ÷ 3
PC 10, Dry-Type, MV, Three-Phase	≥ 95	225-2500	DL 13

* BIL = Basic Impulse insulation Levels
** MV = Medium Voltage
† LV = Low Voltage

To aggregate losses from more than one design line, the Department took a shipments-capacity-weighted average of the per-kilovolt-amper (kVA) transformer characteristics from the economic analysis of the design lines and applied the average per-capacity values to the estimated capacity shipped for each product class. The Department's contractor[1] provided the capacity shipped for each design line (and each product class), the LCC analysis provided the economic results for each design, and the 0.75 rule provided the re-scaled cost and loss estimates for each size category represented by each design line. The following equation provides the average loss per unit capacity of product class ($AvgLossPerCap_{PC}$), as derived from the average loss per unit capacity for a design line:

$$AvgLossPerCap_{PC} = \sum_{DL}\left[AvgLossPerCap_{DL} \times MS_{DL}\right] / \sum_{DL} MS_{DL} \qquad \textbf{Eq. 10.5}$$

where:

$AvgLossPerCap_{DL}$ = the average loss per unit capacity for the design line, and
MS_{DL} = the capacity market share of the design line.

The summation in Equation 10.5 is over those design lines that constitute a product class.

The $AvgLossPerCap_{PC}$ represents the average loss per unit capacity of the transformer load. For no-load losses no more adjustment is needed, but for load losses, the losses at rated load need to be converted to losses at actual loading. The RMS loading is a key factor in estimating load losses at actual loading. The next section describes the RMS loading input.

10.2.2.3 Root Mean Square Loading

The RMS loading is the root mean square of the hourly transformer loading relative to the transformer capacity. Energy losses in transformers follow the RMS load, not the arithmetic average load. The Department calculated the RMS loading as the root mean square of the transformer load, divided by the transformer rated capacity, times the power factor. (As explained in Chapter 6, while the Department's method for analysis can derive results for varying power factors, for the analysis presented here the Department set the power factor to the value of one.) The Department used the average national RMS loading for each design line as calculated in the LCC analysis. These values range between 30.2 percent and 58.9 percent for the different design lines.

10.2.2.4 Load Growth

The fractional load growth is the fraction by which the load has increased since a transformer was installed. Load growth occurs when new equipment, new appliances, or additional activities occur on the circuits served by distribution transformers. Load growth has the impact of increasing the load losses relative to the losses that the Department estimated during the first year of installation.

The Department calculated the fractional load growth from an estimated load growth rate that it used as an input to the LCC analysis. There is a maximum load growth, *LGRMax,* which is set by the Department at 50 percent based on data for liquid-immersed transformers. The 50 percent value represents the approximate amount of growth in load that can occur without overloading the transformer beyond a reasonable point, at which time the transformer is assumed to be relocated and reinstalled with the initial peak loading.[4] See Institute of Electrical and Electronics Engineers, Inc. (IEEE) Std C57.91-1995[5] for details on permissible overloading of mineral-oil immersed transformers. Since IEEE does not report data on permissible overloading of dry-type units, the Department used the same values for both liquid-immersed and dry-type transformers. The age of the transformer at which this point is reached is given by:

$$age_{Max} = \frac{ln(1+LGRMax)}{ln(1+LGR)} \qquad \textbf{Eq. 10.6}$$

where:

age_{Max} = the maximum age of transformer, in years, after which time the load switches to initial peak load, and

LGR = the annual load growth rate (in %).

Thus, the equation for the load growth as a function of the age of the transformer is as follows:

$$LGrwth(age) = (1+LGR)^{(age)}-1 \quad \textbf{Eq. 10.7}$$

for $age < age_{Max}$, and

$$LGrwth(age) = (1+LGR)^{(age-ageMax)}-1 \quad \textbf{Eq. 10.8}$$

for $age >= age_{Max}$

where *LGrwth (age)* is the fractional load growth.

The load growth is then used to adjust the RMS loading estimate for the affected stock. The mathematical equation for this adjustment is as follows:

$$LAdjust(y) = \sqrt{\sum_{age=1}^{y-Std\_year} \left[Stock(y, age) \times (1 + LGrwth(age))^2 \right] / Aff\_Stock(y)} \quad \textbf{Eq. 10.9}$$

where *LAdjust(y)* is the load adjustment factor in year *y* and all other variables have been defined previously.

The Department used a load adjustment factor to calculate an adjusted RMS loading that incorporates load growth into the unit energy consumption as described in the next section.

10.2.2.5 Affected Stock

The affected stock is an output of the shipments model (Chapter 9) and a key input for the NES and NPV calculations. The affected stock consists of that portion of the transformer stock that is potentially impacted by a candidate standard. It therefore consists of those transformers in the stock that are purchased in or after the year the candidate standard has taken effect, as described by the following equation:

$$Aff\_Stock(y) = Ship(y) + \sum_{age=1}^{y-Std\_year} Stock(age) \quad \textbf{Eq. 10.10}$$

where:

Aff_Stock(y)	=	the stock of transformers of all vintages that are operational in year *y,* and
Age	=	the age of the transformer in years.

10.2.2.6 Unit Energy Consumption

One of the final quantities that the Department calculated for the NES estimate is the unit energy consumption for affected stock. The unit energy consumption times the capacity shipped and the site-to-source conversion factor equals the annual energy consumption from which the total national energy savings is derived.

Annual unit energy consumption (*UEC(y)*) for affected stock, or energy per unit capacity, is the annual energy consumption per unit capacity for transformers shipped after the effective date of a standard. This energy consumption is a function of load losses and no-load losses. The Department calculated the losses per transformer as the sum of no-load loss plus the load losses. The Department calculated the load losses as the rated load loss times the square of RMS loading adjusted for load growth. Average energy consumed per unit capacity for affected stock varies from year to year due to load growth affects.

The annual unit energy consumption for distribution transformers for affected stock is given by the following equation:

$$UEC(y) = E_{NL} + E_{LL} \times [RMS \times LAdjust(y)]^2 \qquad \textbf{Eq. 10.11}$$

where:

E_{NL} = rated no-load losses per kVA capacity,
E_{LL} = rated load losses per kVA capacity,
RMS = root mean square, and
$LAdjust(y)$ = loading adjustment factor for year y.

Once the unit energy consumption for affected stock is defined, only one more input is necessary to complete the NES calculation: the site-to-source conversion factor.

10.2.2.7 Electricity Site-to-Source Conversion

The source conversion factor for electricity is the factor by which site energy (in kWh) is multiplied to obtain primary (source) energy (in Btu). Since the NES estimates the change in energy use of the resource (e.g., the power plant), the source conversion factor is necessary to account for losses in generation, transmission, and distribution. After calculating energy consumption at the site, the Department multiplied it by the conversion factor to obtain primary energy consumption, expressed in quads. This conversion permits comparison across (source) fuels by taking into account the heat content of different fuels and the efficiency of different energy conversion processes. The annual values are the U.S. average conversion factors for electricity generation for both peak and base load reduction. The Department used marginal heat rates corresponding to base load for no-load losses (or core-losses) and rates corresponding to peak load for load losses (or coil losses). It used these differential rates because load losses are higher during transformer peak loads while no-load losses occur at all times. The Department obtained these conversion factors using a variant of the NEMS, called NEMS-BT.[a] Table 10.3.2 presents the average annual conversion factors that the Department used.

Table 10.2.2 Average Site-to-Source Conversion Factors for No-Load Losses and Load Losses

Year	For No-Load Losses	For Load Losses
2007	3.370	2.550
2008	3.156	2.403
2009	2.988	2.403
2010	2.820	2.403
2011	2.668	2.403
2012	2.507	2.403
2013	2.508	2.350
2014	2.391	2.296
2015	2.381	2.296
2016	2.415	2.262
2017	2.417	2.237
2018	2.331	2.212
2019	2.335	2.209
2020–35	2.326	2.178

The Department used a time-series projection of conversion factors, changing from year to year, which it calculated as follows:

1. Start with an integrated projection of electricity supply and demand (e.g., the *Annual Energy Outlook*'s (*AEO 2003)* reference case)[7] and extract the source energy consumption.

[a] For more information on NEMS, refer to the U.S. Department of Energy, Energy Information Administration (DOE/EIA) documentation. A useful summary is *National Energy Modeling System: An Overview 2000*.[6] DOE/EIA approves use of the name NEMS to describe only an official version of the model without any modification to code or data. Because the analysis entails some minor code modifications and the model is run under policy scenarios that are variations on DOE/EIA assumptions, the name NEMS-BT refers to the model as used here (BT is DOE's Building Technologies Program, under whose aegis this work was performed).

2. Estimate projected energy savings due to possible standards for each year (e.g., using the NES spreadsheet model).

3. Feed these energy savings back to the NEMS-BT model as a new scenario, specifically a deviation from the reference case, to obtain the corresponding source energy consumption.

4. Obtain the difference in source energy consumption between this candidate standard level scenario and the reference case.

5. Divide the source energy savings in Btu, adjusted for load-specific transmission and distribution losses, by the site energy savings in kWh to provide the time series of conversion factors in Btu per kWh.

The conversion factors change over time and account for the displacement of generating sources. Furthermore, the NES spreadsheet model includes conversion factors for each year of the projection. The Department and stakeholders can examine the effects of alternative assumptions by revising this column of numbers.

The conversion of site energy savings to source energy savings and the summation of energy savings over the forecast period complete the NES calculations. The results section (section 10.4) presents the output from the NES model. The next section describes the technical details of the NPV calculation.

10.3 NET PRESENT VALUE CALCULATION

The Department estimated the national financial impact on consumers from the imposition of new energy-efficiency standards with a national NPV accounting component in the National Impact spreadsheet. The Department combined output of the shipments model with energy savings and financial data from the LCC to calculate an annual stream of costs and benefits resulting from candidate distribution transformer energy efficiency standards. The Department discounted this time series to 2001 and summed its resulting in the national NPV. The Department selected 2001 as the NPV analysis year for consistency with the equipment cost data, which is from 2001.

10.3.1 Net Present Value Overview

The NPV is the present value of the incremental economic impact of a candidate standard level. Like the NES, the NPV calculation started with transformer shipments and transformer stocks, estimates of which are outputs from the shipments model. The Department then obtained estimates of transformer first costs, losses, and average marginal electricity costs from the LCC analysis. The Department proceeded to calculate the amount spent on transformer purchases and installation. The Department then calculated the corresponding operating costs by applying the marginal prices to the energy used (both energy and electricity system capacity) by the stock of transformers for each year, for both a base case and standards case. Over time in the standards case, more-expensive, but more-efficient transformers gradually replace less-efficient transformers. Thus, the operating cost per unit capacity used by the stock of transformers gradually decreases in the standards case relative to the base case while the equipment costs increase. The Department discounted purchases and expenses and operating costs for transformers using a simple national average discount factor. The discount factor converts a future expense or benefit to a present value for that expense or benefit. The difference in present value of all expenses and benefits between the base case and standards scenario is the national NPV impact. The Department calculated the NPV impact from transformers that were purchased between the present and 2035, inclusive, to calculate the total NPV impact from purchases during the forecast period.

Mathematically, NPV is the value in the present time of a time series of costs and savings, described by the equation:

$$NPV = PVS - PVC \qquad \textbf{Eq. 10.12}$$

where:

PVS	=	the present value of electricity savings, and
PVC	=	the present value of equipment costs including installation.

PVS and *PVC* are determined according to the following expressions:

$$PVS = \sum_{y=Std\_year}^{2070} \left[\frac{OC_{Base}}{Cap}(y) - \frac{OC_{Std}}{Cap}(y) \right] \times Aff\_Stock(y) \times Discount\ Factor(y) \qquad \textbf{Eq. 10.13}$$

where:

$OC_{Base}/Cap(y)$	=	operating cost per unit capacity of transformer for the base case in year *y*,
Aff_Stock(y)	=	stock of transformers of all vintages that are operational in year *y*,
y	=	the year (from effective date of the candidate standard to the year when units purchased in 2035 retire), and
Discount Factor(y)	=	discount factor for the year *y* is defined in Eq. 10-14 and the *discount rate* is described in section 10.3.2.7.

$$Discount\ Factor(y) = \frac{1}{(1 + Discount\ Rate)^{(y - reference\ year)}} \qquad \textbf{Eq. 10.14}$$

where:

reference year	=	year 2001.

$$PVC = \sum_{y=Std\_year}^{2070} \left[\frac{FC_{Std}}{Cap}(y) - \frac{FC_{Base}}{Cap}(y) \right] \times Ship(y) \times Discount\ Factor(y) \qquad \textbf{Eq. 10.15}$$

where:

$FC_{Std}/Cap\ (y)$	=	first cost of the transformer per unit of capacity for a candidate standard level S*td* in year *y*. This quantity is defined in Eq. 10.28 and described in section 10.3.2.1.,
Std_year	=	the year standards come into effect, and
Ship (y)	=	shipments of transformers in year *y* for the standards case.

The Department calculated NPV from the projections of national expenditures for distribution transformers, including purchase price (equipment and installation price) and operating costs (electricity and maintenance costs). The Department calculated costs and savings as the difference between a candidate standards case and a base case scenario without national standards. It discounted future costs and savings to the present.

The Department calculated a discount factor from the discount rate and the number of years between the year to which the sum is being discounted (2001) and the year in which the costs and savings occur. The NPV is the sum over time (2004-2070) of the discounted net financial savings.

The following sections describe the inputs specific to the NPV calculation in detail.

10.3.2 Net Present Value Inputs

The NPV model inputs include cost inputs, selected inputs that are important for detailing electricity capacity costs, and several of the inputs used by the NES calculation. This section details those inputs that have not yet been described as part of the NES and shipments models. The specific list of inputs for the NPV is as follows:

1. First Cost

2. Operating Cost

3. Peak Responsibility Factor

4. Initial Peak Load

5. Electricity Price Forecast Scalar

6. Marginal Electricity Costs

7. Discount Rate

The first cost includes all of the initial costs that are incurred with the installation of a transformer. Generally, first cost increases with the increased efficiency that may be required by a candidate standard level. Operating cost includes the annual costs of operating a transformer. In this analysis, operating cost includes both energy and capacity costs for supplying both no-load and load losses. The peak responsibility factor is a necessary input for estimating the capacity costs incurred from load losses at the initial peak load. The electricity price forecast scalar provides the forecasted increase or decrease in electricity prices over the cost accounting period that ranges from 2001 to the year 2070. Marginal electricity costs convert physical transformer loss estimates into financial economic impacts. The discount rate represents the time value of money and allows the Department to estimate the present value of a future monetary cost or benefit.

The next section begins the detailed discussion of NPV inputs with a description of the transformer first costs that the Department used.

10.3.2.1 First Cost

The Department expresses first cost in terms of cost per unit capacity. Specifically, the Department defines the first cost of acquiring a transformer with the following equation:

$$FC/Cap = (P + Install)/Cap \qquad \textbf{Eq. 10.16}$$

where:

FC	=	the first cost,
Cap	=	the rated capacity of the transformer,
P	=	the price of the transformer including shipping and taxes, and
Install	=	the installation cost of the transformer.

In the NPV calculation, these values are obtained from the LCC calculation as the averages for specific design lines. The Department applied an adjustment factor to convert the first cost of a representative design to an estimated average cost for a distribution of sizes within a particular product class. The adjustment incorporates the 0.75 scaling rule as described in the NES section and the design line to product class mapping. This adjustment factor is explained in detail in sections 10.2.2.1 and 10.2.2.2. The costs are expressed in units of 2001 dollars per kVA of rated transformer capacity.

Table 10.3.1 shows the resulting mean first costs per kVA for distribution transformers by product class and candidate standard level.

Table 10.3.1 First Cost of Distribution Transformers by Candidate Standard Levels and Product Class (2001$/kVA)

Product Class	Base	CSL 1*	CSL 2	CSL 3	CSL 4	CSL 5
PC 1, Liquid-Immersed, MV, Single-Phase	64.80	65.76	68.9	77.94	87.01	97.35
PC 2, Liquid-Immersed, MV, Three-Phase	18.39	19.32	20.45	24.66	25.86	29.81
PC 3, Dry-Type, LV, Single-Phase	58.14	63.13	66.9	66.93	74.09	78.53
PC 4, Dry-Type, LV, Three-Phase	35.97	36.84	38.36	41.12	46.99	56.22
PC 5, Dry-Type, MV, Single-Phase	22.47	25.59	27.08	29.06	34.29	38.69
PC 6, Dry-Type, MV, Three-Phase	17.76	21.47	22.32	24.14	28.63	31.5
PC 7, Dry-Type, MV, Single-Phase	29.10	32.46	34.10	38.04	42.7	46.88
PC 8, Dry-Type, MV, Three-Phase	19.78	22.12	23.29	26.57	30.29	33.77
PC 9, Dry-Type, MV, Single-Phase	12.57	20.01	22.17	26.56	28.02	35.45
PC 10, Dry-Type, MV, Three-Phase	20.77	22.27	24.39	28.99	30.43	38.25

*CSL = Candidate Standard Level

The next section presents the operating costs, which are substantially more complex than the transformer first costs.

10.3.2.2 Operating Cost

Operating costs are an essential, yet complex, part of calculating national economic impact from a candidate distribution transformer standard. The Department used eleven distinct inputs to calculate operating costs. This large number of inputs is necessary because transformers have both no-load and load losses, and because electricity has both energy and capacity costs. The combination of distinct losses and distinct capacity and energy costs creates the necessity for four price and two loss coefficients. Potential load growth requires a load growth adjustment factor. Peak loading, peak load coincidence, and average loading require three additional factors to characterize load losses. Finally, the Department used an electricity price forecast scalar to characterize future trends in electricity prices consistent with the AEO forecast.

Transformer operating cost is the annual cost of transformer losses. The Department assumed zero maintenance cost in calculating the transformer operating cost. The Department calculated annual operating cost using the following formula to capture the diversity of potential factors that can affect transformer operating costs:

$$OC/Cap = EPFS(y) \times (E_{NL} \times (NLLMCC + 8760 \times NLLMEC) + E_{LL} \times (LAdjust(y))^2 \times (PRF \times PL^2 \times LLMCC + 8760 \times RMS^2 \times LLMEC))/Cap \qquad \textbf{Eq. 10.17}$$

where:

OC	=	the operating cost,
Cap	=	the rated capacity of the transformer,
EPFS(y)	=	the electricity price forecast scalar for year *y*,
E_{NL}	=	the no-load losses at rated load,
NLLMCC	=	the no-load loss marginal cost of capacity,
NLLMEC	=	the no-load loss marginal energy cost,
E_{LL}	=	the load losses at rated load,
LAdjust(y)	=	the load growth adjustment factor in year *y*,
PRF	=	the peak responsibility factor,
PL	=	the initial peak load,
LLMCC	=	the load loss marginal cost of capacity,
RMS	=	the root mean square loading of the transformer, and
LLMEC	=	the load loss marginal energy cost.

The Department expressed the costs in units of 2001 dollars per kVA of rated capacity. One additional complexity in the operating cost equation that is shared with the NES calculation, is that the Department applied an adjustment factor to incorporate the 0.75 rule to E_{NL} and E_{LL}, as explained in sections 10.2.2.1 and 10.2.2.2, to convert from design line data to product class estimates.

The following four sections explain the inputs of the operating cost equation that are not explained in the NES section.

10.3.2.3 Peak Responsibility Factor

The peak responsibility factor (PRF), in combination with the initial peak loading, is necessary for estimating the capacity cost impacts of transformer load losses. The transformer PRF is the square of the ratio of the transformer load at the time of the customer peak load to the transformer peak load. The Department used the average PRF from the hourly and/or monthly load analysis for the liquid-immersed and dry-type transformers, respectively, as reported in the LCC analysis. Table 10.3.2 presents the PRFs used in the analysis for the ten product classes.

Table 10.3.2 Peak Responsibility Factors by Product Class

	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7	PC 8	PC 9	PC 10
PRF	0.37	0.61	0.47	0.49	0.50	0.53	0.51	0.53	0.54	0.54

10.3.2.4 Initial Peak Load

The initial peak loading, in combination with the PRF, is necessary for calculating capacity cost impacts from transformer load losses. The initial peak loading is the annual per-unit peak load on the transformer during the first year of operation. The initial peak load is estimated as a percentage of the rated peak load of the transformer. The IEEE's *Draft Guide for Distribution Transformer Loss Evaluation*[4] defines a similar but distinct measure of peak transformer loading called an "Equivalent Annual Peak Load" that accounts for changes in peak load over the life of the transformer. Rather than use the equivalent annual peak load method, the Department characterized a range of possible initial peak loads by defining a distribution of initial peak loads. Chapter 6, section 6.3.4 provides further description. Table 10.3.3 presents the initial peak loadings used in the analysis for the ten product classes.

Table 10.3.3 Initial Peak Loading by Product Class

	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7	PC 8	PC 9	PC 10
Initial Peak Loading	0.85	0.85	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75

10.3.2.5 Electricity Price Forecast Scalar

The electricity price forecast scalar converts current electricity costs for forecasted costs for the period 2001 to 2070. The electricity price forecast scalar is the ratio of the unit cost of electricity in real dollars in a given year to the real cost of electricity in the year 2001. The Department used *AEO 2003* forecasts to obtain the electricity price forecast scalar. For the period beyond 2025, the Department used the real price trend from 2015 to 2025 to extrapolate the electricity price scalar.

10.3.2.6 Marginal Electricity Costs

The characterization of four distinct marginal electricity costs is necessary to calculate the operating costs of transformers and the financial impact of distribution transformer efficiency standards. In an electricity system, there are both energy costs and capacity costs. Depending on the load shape of a particular load, the average value of capacity costs and energy costs are distinct. Since no-load losses and load losses have distinct load shapes compared to each other and since different customers have different load shapes, such costs vary by loss type and by the product class of the transformer. The Department therefore used distinct marginal energy and capacity costs for no-load losses and load losses for each transformer product class. No transformer size scaling is necessary for the marginal costs, although the design-line-to-product-class mapping described in section 10.2.2.2 needs to be applied to convert the design line output from the LCC to product class information for the NPV calculation. The Department calculated capacity costs in units of 2001$/kW/year, while energy costs are in units of 2001$/kWh. The names for the four types of marginal cost are: no-load loss marginal capacity cost (*NLLMCC*), load loss marginal capacity cost (*LLMCC*), no-load loss marginal energy cost (*NLLMEC*), and load loss marginal energy cost (*LLMEC*). Table 10.3.4 summarizes the four marginal costs for the ten product classes.

Table 10.3.4 Marginal Energy and Demand Cost by Product Class

Marginal Demand Cost by Product Class ($/kW)										
	PC 1	**PC 2**	**PC 3**	**PC 4**	**PC 5**	**PC 6**	**PC 7**	**PC 8**	**PC 9**	**PC 10**
NLL	102.3	117.7	79.2	85.3	87.9	88.5	87.7	88.6	89.1	89.1
LL	55.1	61.6	55.2	61.4	61.4	68.7	67.4	68.9	70.3	70.3
Marginal Energy Cost by Product Class ($/kWh)										
	PC 1	**PC 2**	**PC 3**	**PC 4**	**PC 5**	**PC 6**	**PC 7**	**PC 8**	**PC 9**	**PC 10**
NLL	0.025	0.025	0.059	0.055	0.053	0.053	0.053	0.053	0.052	0.052
LL	0.035	0.032	0.061	0.057	0.055	0.055	0.055	0.055	0.055	0.055

10.3.2.7 Discount Rate

The discount rate expresses the time value of money, and is the final input to the NPV calculation. The Department used a real discount rates of 3.0 and 7.0 percent as established by the Office of Management and Budget (OMB) in Circular A-4, *Regulatory Analysis*.[8] The discount rates that the Department used in the LCC are distinct from those it used in the NPV calculations, in that the LCC discount rates reflect the owner cost of capital and the financial environment of electric utilities and commercial and industrial entities.

10.4 RESULTS

10.4.1 National Energy Savings and Net Present Value from Candidate Standard Levels

The NES and NPV results from the NES spreadsheet model for CSL 1 through CSL 5 are shown in Table 10.4.1. Tables 10.4.2 and 10.4.3 present NPV and NES results for liquid-immersed transformers by product class. Tables 10.4.4 and 10.4.5 present NPV and NES results for dry-type transformers by product class. It should be reiterated that, currently, the NES spreadsheet model uses discrete point-values rather than a distribution of values for all inputs.

Table 10.4.1 Summary of Cumulative NES (2007-2035) and NPV (2007-2070) Impact

Distribution Transformers	Analysis	Discount Rate (percent)	Candidate Standard Level				
			CSL 1	CSL 2	CSL 3	CSL 4	CSL 5
Liquid-immersed	NES (quads)		1.90	3.04	5.22	6.97	7.86
	NPV (billion 2001$)	3	6.56	8.33	6.45	5.10	-0.79
		7	1.68	1.50	-1.21	-3.19	-7.39
Dry-type	NES (quads)		4.98	5.75	6.71	7.46	8.18
	NPV (billion 2001$)	3	32.83	37.24	41.95	43.80	44.45
		7	10.09	11.27	12.39	12.25	11.41

Figures 10.4.1 through 10.4.4 illustrate the typical pattern of national savings and costs resulting from standards for liquid-immersed and dry-type transformers over time. The figures show the nature of net savings for all five candidate standard levels relative to the base case.

10.4.1.1 Liquid-Immersed Results

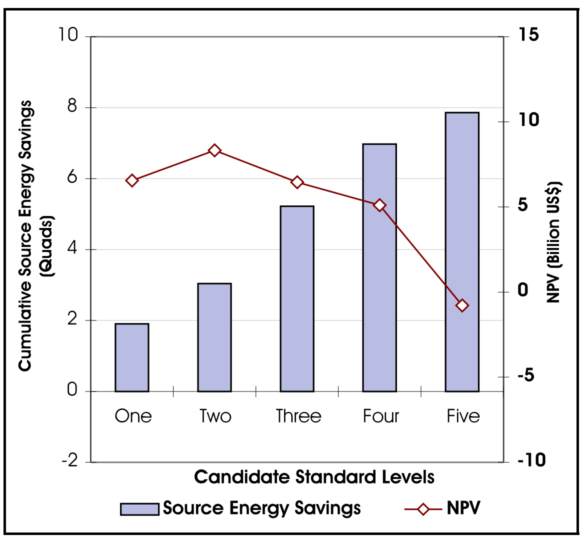

Figure 10.4.1 Liquid-Immersed Distribution Transformers: NES and NPV Impacts: 3% Discount Rate

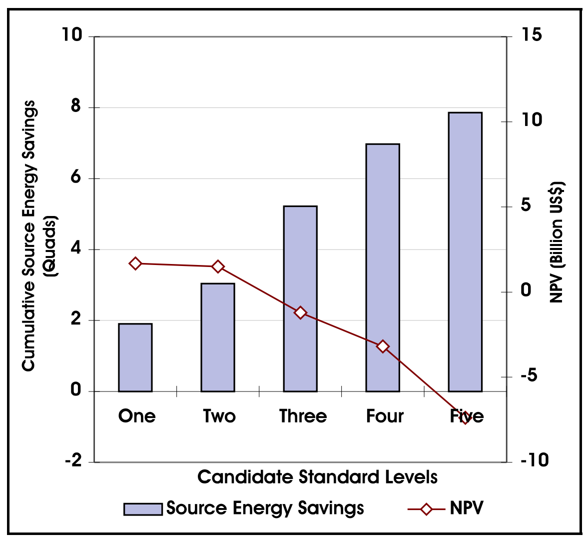

Figure 10.4.2 Liquid-Immersed Distribution Transformers: NES and NPV Impacts: 7% Discount Rate

Table 10.4.2 Net Present Value During 2007-2070: Liquid-Immersed Transformers by Product Class

Product Class	Net Present Value ($Billions)									
	Discount Rate: 3 percent					Discount Rate: 7 percent				
	CSL 1	CSL 2	CSL 3	CSL 4	CSL 5	CSL 1	CSL 3	CSL 3	CSL 4	CSL 5
1. Liquid-immersed, medium-voltage, single-phase	2.96	3.03	0.42	-1.30	-7.12	0.78	0.30	-1.88	-3.77	-7.18
2. Liquid-immersed, medium-voltage, three-phase	3.59	5.30	6.03	6.41	6.33	0.90	1.20	0.67	0.58	-0.21
Total	**6.56**	**8.33**	**6.45**	**5.10**	**-0.79**	**1.68**	**1.50**	**-1.21**	**-3.19**	**-7.39**

Table 10.4.3 Cumulative Primary Energy Savings During 2007-2035: Liquid-Immersed Transformers by Product Class

Product Class	Cumulative Primary Energy Savings (Quads)				
	CSL 1	CSL 3	CSL 3	CSL 4	CSL 5
1. Liquid-immersed, medium-voltage, single-phase	0.94	1.48	2.59	3.97	4.26
2. Liquid-immersed, medium-voltage, three-phase	0.96	1.55	2.63	3.01	3.60
Total	**1.90**	**3.04**	**5.22**	**6.97**	**7.86**

10.4.1.2 Dry-Type Results

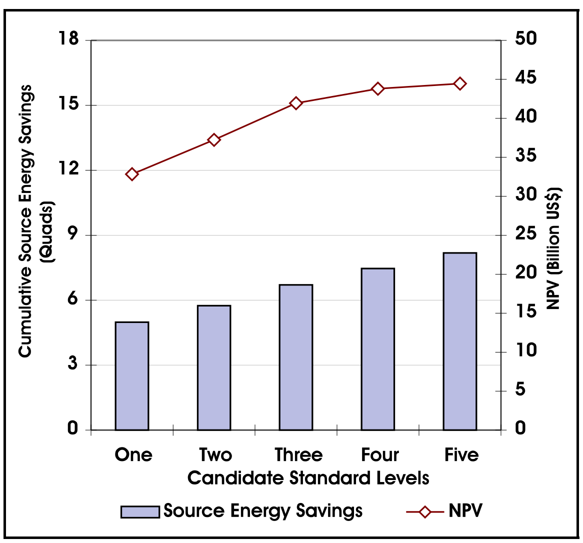

Figure 10.4.3 Dry-Type Distribution Transforms: NES and NPV Impacts: 3% Discount Rate

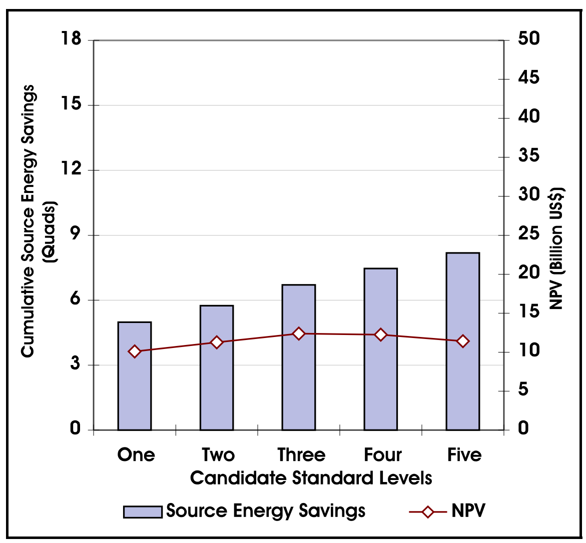

Figure 10.4.4 Dry-Type Distribution Transforms: NES and NPV Impacts: 7% Discount Rate

Table 10.4.4 Net Present Value During 2007-2070: Dry-Type Transformers by Product Class

Product Class	Net Present Value ($Billions)									
	Discount Rate: 3 percent					Discount Rate: 7 percent				
	CSL 1	CSL 2	CSL 3	CSL 4	CSL 5	CSL 1	CSL 3	CSL 3	CSL 4	CSL 5
3. Dry-type, low-voltage, single-phase	2.34	2.52	2.58	2.62	2.61	0.71	0.74	0.76	0.74	0.72
4. Dry-type, low-voltage, three-phase	29.14	32.99	37.07	38.85	39.68	9.03	10.07	11.07	11.04	10.37
5. Dry-type, medium-voltage, single-phase, 20-45 kV BIL	0.0073	0.0084	0.0099	0.0102	0.0098	0.0021	0.0023	0.0027	0.0025	0.0021
6. Dry-type, medium-voltage, three-phase, 20-45 kV BIL	0.32	0.36	0.42	0.42	0.40	0.08	0.09	0.11	0.09	0.07
7. Dry-type, medium-voltage, single-phase, 46-95 kV BIL	0.0055	0.0070	0.0087	0.0087	0.0084	0.0015	0.0018	0.0021	0.0017	0.0013
8. Dry-type, medium-voltage, three-phase, 46-95 kV BIL	0.93	1.24	1.71	1.73	1.63	0.25	0.32	0.41	0.34	0.24
9. Dry-type, medium-voltage, single-phase, $\geq$96 kV BIL	0.0006	0.0009	0.0011	0.0013	0.0009	0.0002	0.0002	0.0002	0.0003	0.0001
10. Dry-type, medium-voltage, three-phase, $\geq$96 kV BIL	0.09	0.13	0.14	0.17	0.12	0.02	0.03	0.03	0.04	0.01
Total	**32.83**	**37.24**	**41.95**	**43.80**	**44.45**	**10.09**	**11.27**	**12.39**	**12.25**	**11.41**

Table 10.4.5 Cumulative Primary Energy Savings During 2007-2035: Dry-Type Transformers by Product Class

Product Class	Cumulative Primary Energy Savings (Quads)				
	CSL 1	CSL 3	CSL 3	CSL 4	CSL 5
3. Dry-type, low-voltage, single-phase	0.35	0.38	0.39	0.42	0.43
4. Dry-type, low-voltage, three-phase	4.39	5.07	5.87	6.53	7.20
5. Dry-type, medium-voltage, single-phase, 20-45 kV BIL	0.0012	0.0014	0.0017	0.0020	0.0021
6. Dry-type, medium-voltage, three-phase, 20-45 kV BIL	0.05	0.06	0.08	0.09	0.09
7. Dry-type, medium-voltage, single-phase, 46-95 kV BIL	0.0010	0.0012	0.0017	0.0019	0.0021
8. Dry-type, medium-voltage, three-phase, 46-95 kV BIL	0.17	0.21	0.33	0.38	0.41
9. Dry-type, medium-voltage, single-phase, $\geq$96 kV BIL	0.0001	0.0002	0.0002	0.0003	0.0003
10. Dry-type, medium-voltage, three-phase, $\geq$96 kV BIL	0.02	0.02	0.03	0.04	0.04
Total	**4.98**	**5.75**	**6.71**	**7.46**	**8.18**

10.5 SPREADSHEET DESCRIPTION AND INSTRUCTIONS

10.5.1 Spreadsheet Description

The transformer national impact spreadsheet has two components: a) Shipments and b) NES/NPV. The shipments component contains all of the necessary input information and calculations to forecast transformer shipments by product class for candidate standard levels. The national impact spreadsheet is contained in a Microsoft Excel file available at the DOE website:
http://www.eere.energy.gov/buildings/appliance_standards/commercial/dist_transformers.html

10.5.1.1 Introduction

This worksheet provides an outline of the contents of the entire national impact spreadsheet and describes the function of individual worksheets.

10.5.1.2 Model Flowchart

This worksheet presents the flowchart of the shipments and the NES modules.

10.5.2 NES/NPV

The purpose of the NES/NPV part of the national impact spreadsheet is to calculate some of the key quantities by which a candidate energy efficiency standard may be evaluated. Two such quantities are national source energy savings and NPV. Source energy is total energy saved (or reduction in losses) by transformers. NPV is a measure of the net benefit to consumers due to an energy-efficiency standard. This section provides a basic description of the NES module and its various component worksheets.

10.5.2.1 Input Worksheets

There are several worksheets that contain data from other sources, which are used in the calculation of the NES and NPV. These worksheets are:

10.5.2.2 Shipments and Affected Stock (from "Stock" sheets)

To forecast energy savings from transformers as a result of a standard, it is crucial to have an accurate estimate of transformer shipments and subsequent efficiency of the stock. The shipments calculation comprises its own analysis, described earlier in this chapter. The NES calculation references shipments and affected stock data from the "Stock" sheets (12 in all—6 sheets each for liquid-immersed and dry-type transformers for the base case and the candidate standard levels).

10.5.2.3 Marginal Prices

The "LCC Data by Product Class" worksheet contains the marginal energy price and the demand price data. Marginal prices, which differ from average prices, are used to calculate savings in operating cost due to improved efficiency of the transformer stock. This worksheet also contains energy loss (or consumption) data, referred to as the load and the no-load loss data, for different product classes. The data in this worksheet use an estimate of the market share (from the "Market Share Data" worksheet) by efficiency level to calculate average values of equipment cost, load, and no-load losses for each standard level.

10.5.2.4 Site2Source

This worksheet contains the conversion factors for calculating source energy from site energy. Site energy is the energy saved by a transformer itself. Source energy includes all energy used in the production and delivery of the energy to the site. Source energy consumption has general economic, industrial, and environmental effects and is therefore a key indicator of the desirability of any candidate standard.

10.5.2.5 Calculation Worksheet

This worksheet performs all of the calculations necessary for an assessment of NPV and source energy savings. The algorithm of the model is implemented by applying formulae to input data contained in the above worksheets. The calculation worksheet also serves a 'tracking' function, displaying intermediate results for each year.

10.5.2.6 Annual Impacts

This worksheet makes several calculations for the base case (in the absence of a national standard) as well as all the candidate standard levels. Savings are calculated as the difference between the base case and the candidate standard level energy consumption. The total equipment costs for each year are derived from shipments and average first costs (retail price plus installation costs). The total fuel cost savings are calculated by combining unit fuel prices, and the load and no-load losses of the transformer units in stock (affected stock, in this case). The capacity savings are calculated using the marginal demand price along with the load and no-load losses of the transformer units in stock. Finally, the total source energy savings of the transformers is calculated using the marginal heat rates located in the "Site2Source" worksheet.

10.5.2.7 Output Worksheets

The output worksheets serve two purposes. First, they provide both detailed and summarized results of the calculation worksheets. Second, they serve as an interface to the utility impact and national employment analyses that DOE will conduct at a later stage of this rulemaking.

10.5.2.8 Output

This worksheet presents the consolidated outputs produced for each product class when the user runs the macro for *All Classes*. The *All Classes* button is on the "Summary of Results" worksheet. Total savings and NPV for the forecast period are summarized in tables for each standard level. For convenience, these results are also summarized on the "Summary of Results" worksheet.

10.5.2.9 Summary of Results

In addition to providing the summaries of NES and NPV for each standard level, this worksheet presents a graph of the NES and NPV across standard level by product class.

10.5.2.10 Charts

This worksheet displays the savings charts for years 2007 through 2035 produced for all the candidate standard levels when the user runs a specific scenario or a product class in the "Summary of Results" sheet.

10.6 USING THE SPREADSHEET

The "Summary of Results" worksheet serves as the user interface for running the model for a particular product class. To provide flexibility, the spreadsheet facilitates some user modifications to the model. The user may select a particular macroeconomic forecast which determines fuel prices, electricity sales, and income data to be used by the model. The user may also directly input new values for implicit discount rates, which quantify consumer preference for immediate, instead of delayed, savings. Additionally, the user can make a selection for long-term purchase elasticity for transformers.

The *All Classes* button on the "Summary of Results" worksheet runs the model for all classes and creates a summary of outputs in the "Output" sheet.

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